SUPERADIABATIC LAPSE RATES OF TEMPERATURE IN RADIOSONDE OBSERVATIONS

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ABSTRACT

Some instances of superadiabatic lapse rates in temperature observed in radiosonde observations may be produced or accelerated by adiabatic lifting. Examples are shown which suggest this possibility.

Lapse rates of temperature which are greater than the dry adiabatic rate are occasionally observed at most radiosonde stations and are frequently observed at some stations. Many observers and forecasters seem to have some resistance toward recognizing the existence of a superadiabatic lapse rate in the free atmosphere. Due principally to this resistance, the radiosonde observations showing superadiabatic lapse rates have frequently been attributed to some error on the part of the observer or to some defect or characteristic of the radiosonde, the most common of which has come to be called the "wet bulb effect"; i. e., a temperature error of the radiosonde due to evaporative cooling just above cloud tops. The recorder record usually shows that the change of temperature actually occurred, but whether this change is produced by some meteorological condition or by some characteristic of the instrument is unknown. Thus the correct interpretation of the record is in doubt. It is recognized that the thermistor may acquire water droplets as the radiosonde goes through a cloud or rain and upon emerging into dry air shows an error in temperature due to evaporative cooling. However, superadiabatic lapse rates frequently occur on a selective basis; i. e., they sometimes occur in cases having small chance of error due to evaporative cooling, such as short time of exposure to clouds or slow rate of decrease in humidity at the cloud tops, but on occasion do not occur in cases having very good chance of error.

Several different types of superadiabatic lapse rates occur, some of which are obviously real atmospheric phenomena such as those occurring with an increase of relative humidity [1]. Another very frequent type of superadiabatic lapse rate is observed at or near cloud tops. It occurs in a thin layer where a very dry mass of air overlies a saturated mass. A strong inversion is frequently observed near the base of the dry air. Cumuliform clouds are usually reported, varying from 0.3 cloudiness to overcast. It is generally recognized that these superadiabatic lapse rates could be either a "wet bulb effect" of the instrument (i. e., the wet thermistor indicates its wet bulb temperature upon emerging from the cloud) or some physical phenomenon associated with the physics of clouds (such, for example, as evaporative cooling of the cloud top [2], or cooling at the saturated-dry air interface due to lifting, or a combination of these effects). That the rapid changes of temperature seem to occur at times when a dry mass of air overlies a saturated or near-saturated layer of warm air implies a geographical distribution of the stations showing layers with superadiabatic lapse rates. A preliminary survey indicates that these layers are prevalent around the edges of the oceanic Highs and along the Gulf coast, particularly at those stations where strong inversions occur near the cloud tops.

A survey of the stations showing high frequency of superadiabatic lapse rates at or near cloud tops indicated that Hilo, Hawaii, had a large number of such occurrences. During May and June 1950, 51 radiosonde observations at Hilo, out of a total of 122, showed superadiabatic lapse rates at or near cloud tops. The thickness of the layers showing superadiabatic lapse rates varies from approximately 30 mb. to some value much less than the radiosonde is capable of measuring. In a few cases, a thickness of 4 mb. was indicated. Since 4 or 5 mb. in the 600- to 800-mb. region represents a time interval equivalent to the response time of the thermistor, an instantaneous humidity discontinuity would be required for this to be a wet bulb indication of the thermistor. It is also of interest that practically all these observations of superadiabatic lapse rates at Hilo occurred at temperatures above freezing.

In several of the observations at Hilo, and also in some sections of the United States, a comparison of the observation showing a superadiabatic lapse rate near the cloud top with the preceding observation indicated that cooling may have occurred at the saturated-dry air interface due to adiabatic lifting between the two observations. Hilo

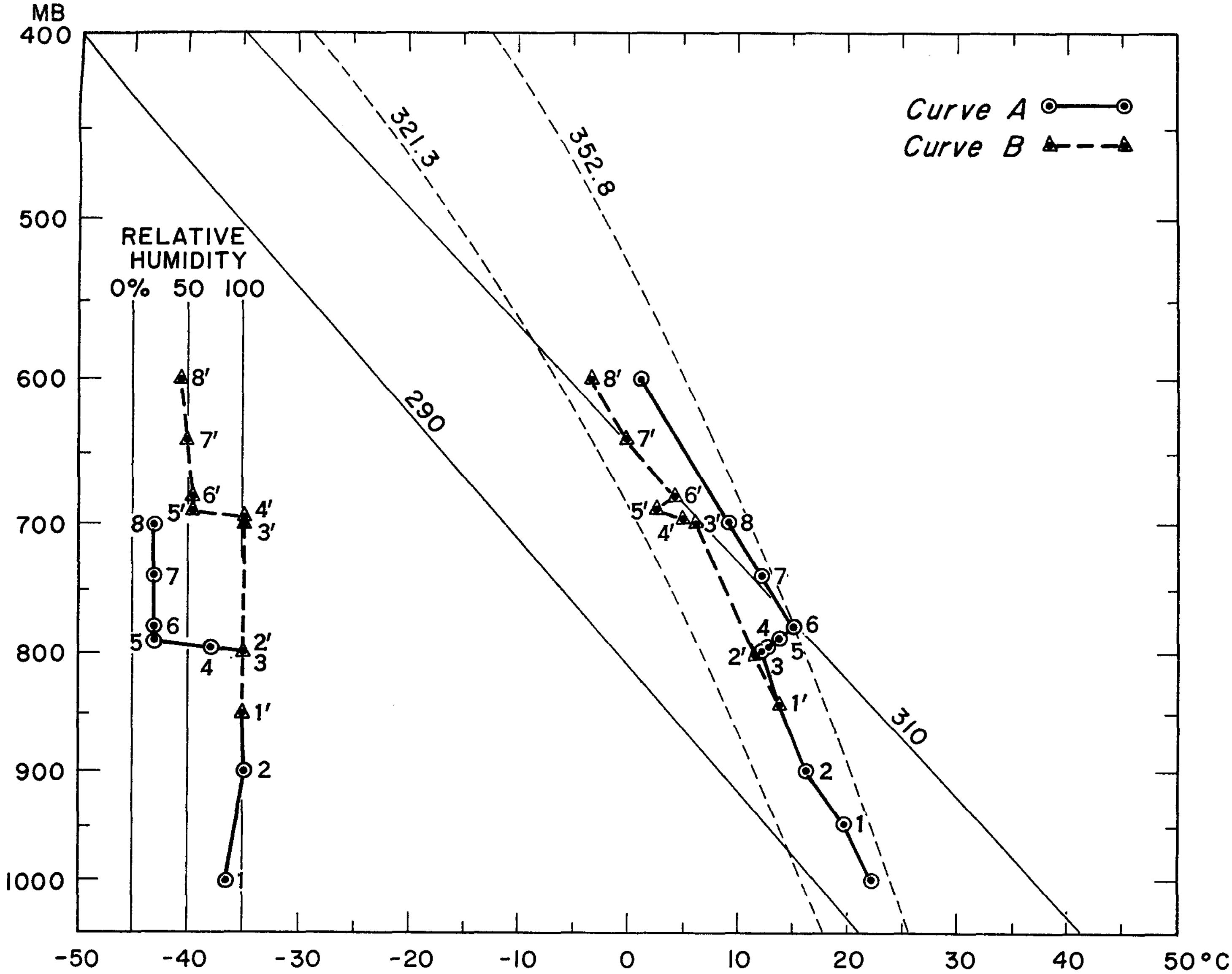

Figure 1.—An assumed observation (Curve A) when lifted adiabatically without change produces Curve B.

offers an excellent example where orographic lifting may occur frequently and may be a contributing factor in producing many of the superadiabatic lapse rates.

Assume a pressure, temperature, humidity relationship such as that shown in Curve A, figure 1. If the layer of air between levels 1 and 7 is lifted adiabatically 100 mb. (lift the dry air along the dry adiabatic lapse rate until saturated and then along the saturated adiabatic lapse rate, and lift the saturated air along the saturated adiabatic lapse rate), the pressure-temperature curve shown in Curve B results, assuming no changes other than those due to adiabatic lifting. A superadiabatic lapse rate will be produced in a thin layer of air just above the saturated air mass.

Figures 2 and 3 show two pairs of successive radiosonde observations at Hilo. In each case the first observation is shown as Curve A, the following observation as Curve B dashed line. If that portion of the air mass indicated by the numbers is lifted adiabatically, assuming the layer of the air at the base of the inversion is saturated before lifting begins, Curve C, solid line, results. (Point 1, Curve A, is lifted to 1′, Curve C; 2 to 2′, etc.) The similarity between the calculated sounding, Curve C, and the observed second sounding, Curve B, is striking. In each case the amount of lifting assumed is indicated on the figure. It seems reasonable to assume that a small layer of air near the base of the inversion is saturated before lifting began since in each case low clouds are reported at the first observation.

Cooling due to adiabatic lifting is offered as a suggested explanation for at least part of the cooling effect observed in some of the superadiabatic lapse rates near cloud tops.

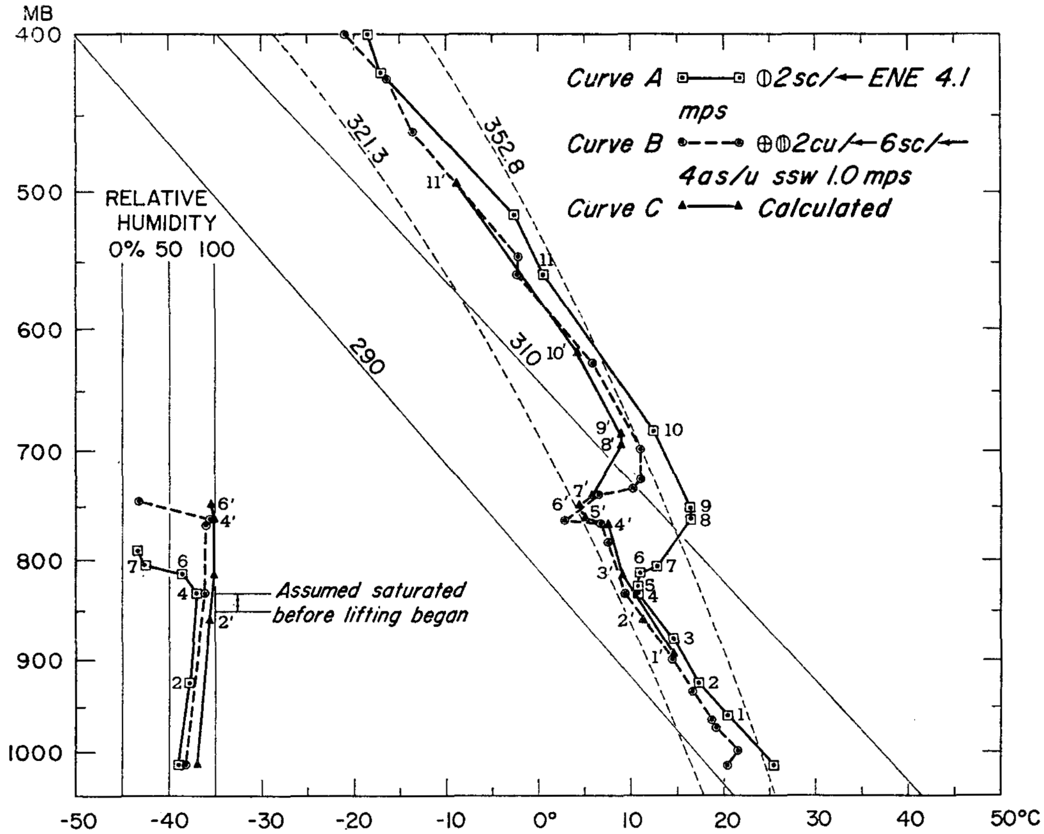

FIGURE 2.—Two successive soundings at Hilo, Hawaii. If the earlier sounding is lifted adiabatically 65 mb. a calculated sounding result which is similar to the later observation. Curve A: June 17, 1950, 0300 GMT. Curve B: June 17, 1950, 1500 GMT. Curve C: Calculated

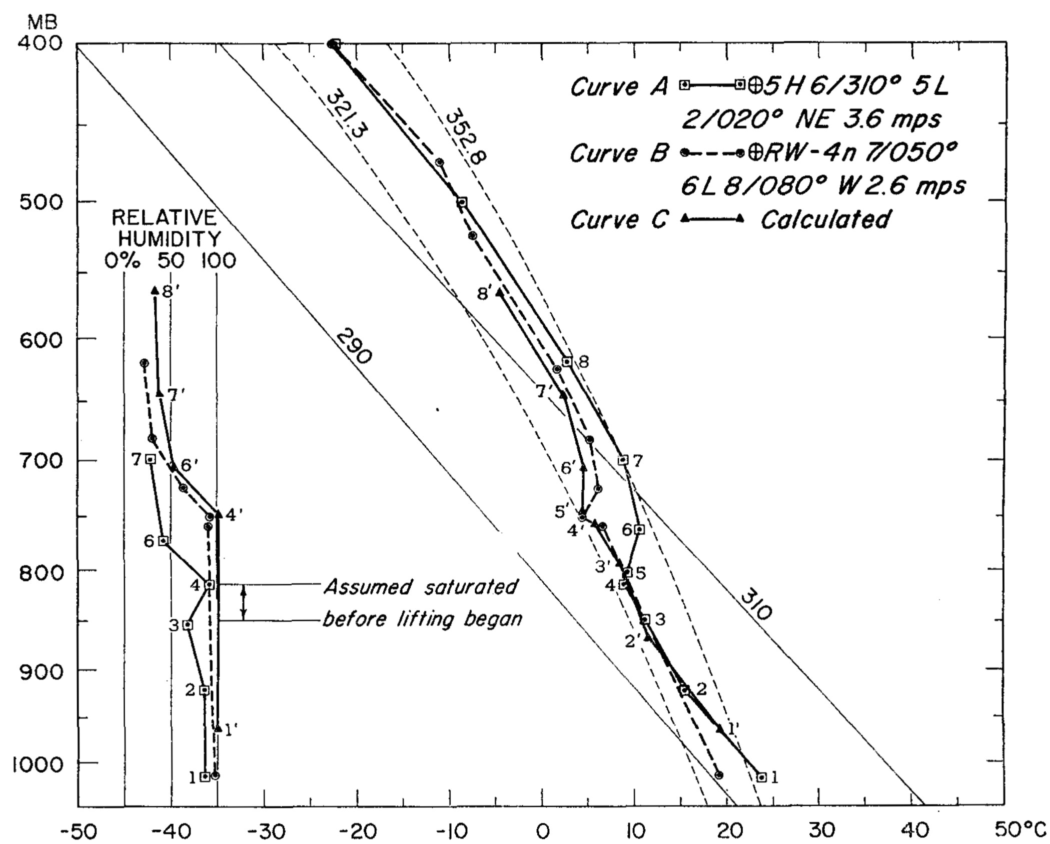

FIGURE 3.—Two successive soundings at Hilo, Hawaii. If the earlier sounding is lifted adiabatically 55 mb., a calculated sounding results which is similar to the later observation. Curve A: May 3, 1950, 0300 GMT. Curve B: May 3, 1950, 1550 GMT. Curve C: Calculated.

It must be emphasized that all superadiabatic lapse rates at or near cloud tops should not be treated indiscriminately as an indication of adiabatic lifting. Certainly other concurrent changes in atmospheric conditions are important and should not be minimized. Furthermore, certain types of radiosondes, such as the ones using the exposed white-coated thermistors, may be more susceptible to collecting and freezing of small water droplets from which instrumental superadiabatic lapse rates may result, than those which protect the thermistor in a ventilating duct from direct impingement of rain and cloud droplets. It may be that the observed phenomenon is the combination of several processes, such as (1) cooling at the saturated-dry air interface due to adiabatic lifting, (2) evaporative cooling at the cloud top, and (3) evaporative cooling of the thermistor, if wet, as it emerges from the cloud top.

This discussion resulted from continuing studies on accuracies and performance characteristics of the radiosonde. Being incidental to instrumental problems, it should be considered as a reminder of a phenomenon for further study. In view of the recent interest in unusual soundings in the study of severe storms [3] and in local situations such as that at Hilo, it seems to be an opportune time to bring this to the attention of the forecasters and research workers for whatever value it might have to them. It is recognized that the problem is indeed a complex one and no easy solution is currently available.

REFERENCES

1. D. Brunt, *Physical and Dynamical Meteorology*, 2d Edition, Cambridge, University Press, 1939, p. 44.
2. Morris Neiburger, "Temperature Changes During Formation and Dissipation of West Coast Stratus," Weather Bureau *Research Paper* No. 19, Washington, July 1944.
3. H. C. McComb and R. G. Beebe, "A Thunderstorm Sounding," *Monthly Weather Review*, vol. 84, No. 3, March 1956, p. 107.

CORRECTION

Monthly Weather Review, vol. 84, No. 2, p. 72: The report of a surface temperature of −102° F. at Verkhoyansk in February 1956 was subsequently amended to −70° F. (See *Weather*, vol. XI, No. 3, March 1956.)